How do Hydrogen Fuel Cell Vehicles Compare in Terms of Emissions and Energy Use? A Well-to-Wheel Analysis

Well-to-Wheel analysis is a systems approach to assessing the energy consumption and greenhouse gas emissions associated with different fuels and vehicle propulsions systems. A well-to-wheel analysis takes into account energy use and emissions at every stage of the process, from the moment the fuel is produced at the "well" to the moment the "wheels" are moved. For example, using this type of analysis, a vehicle with a diesel powered internal combustion engine can be directly compared to a fuel cell vehicle that uses hydrogen made from natural gas, both in terms of emissions and energy use. This is particularly important when considering hydrogen fuel cell vehicles since there are numerous ways to produce hydrogen, some of which are clean and efficient and others which are polluting and energy intensive. [1]

Two recent studies, one European and one North American, analyze well-to-wheel energy use and greenhouse gas emissions (CO2) for a wide range of fuels and vehicle propulsion systems. The studies are:

- "Well-to-Wheel Analysis of Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – A European Study," by General Motors, Ludwig Bolkow Systemtechnik, BP, ExxonMobil, Shell, and TotalFinaElf, May 2002.
- "Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems – North American Analysis," by General Motors, Argonne National Laboratory, BO, ExxonMobil, and Shell, June 2001.

While the reports themselves analyze the whole universe of fuels, fuel pathways, and propulsion systems, the graphs below highlight findings related to the two most common ways to produce hydrogen (reformation of natural gas and electrolysis of water) and some variations (centralized production vs. on-site at gas stations and conventional power mix vs. wind power). It compares these scenarios with conventional gasoline, diesel, and hybrid electric vehicles.

The European study concludes that, with the exception of renewables, fuel cell hybrid vehicles (FCHV) using compressed hydrogen reformed from natural gas have the lowest greenhouse gas emissions (GHG) on a well-to-wheel basis. They also consume/require the least amount of energy on well-to-wheel basis, tying with FCHVs using hydrogen produced from electrolysis of renewable wind power. Of course, GHG emissions associated with hydrogen made from wind energy and electrolysis are zero. FCHVs using hydrogen produced via electrolysis and the current EU power mix are both energy intensive and high in GHG emissions due to the fact that coal and other fossil fuels are used to produce the electricity. (See Figures 1 & 2).

Similarly, the North American study shows that the fuel cell vehicles using compressed hydrogen reformed from natural gas have lower total system energy use (Btu/mi) than conventional gasoline and diesel vehicles. Likewise, GHG emissions were lowest on a well-to-wheel basis for the FCHVs using hydrogen reformed from natural gas. FCHVs using hydrogen produced from electrolysis and the current US power mix are very energy intensive and high in GHG emissions due to the fact that much of US electrical power is derived from coal and other fossil sources. The North American study did not look at hydrogen produced from renewable power. (See Figures 3 & 4).

[1] See EIN fact sheet, "Where Does Hydrogen Fuel Come From?"

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A Well-to-Wheel Analysis

Figure 1

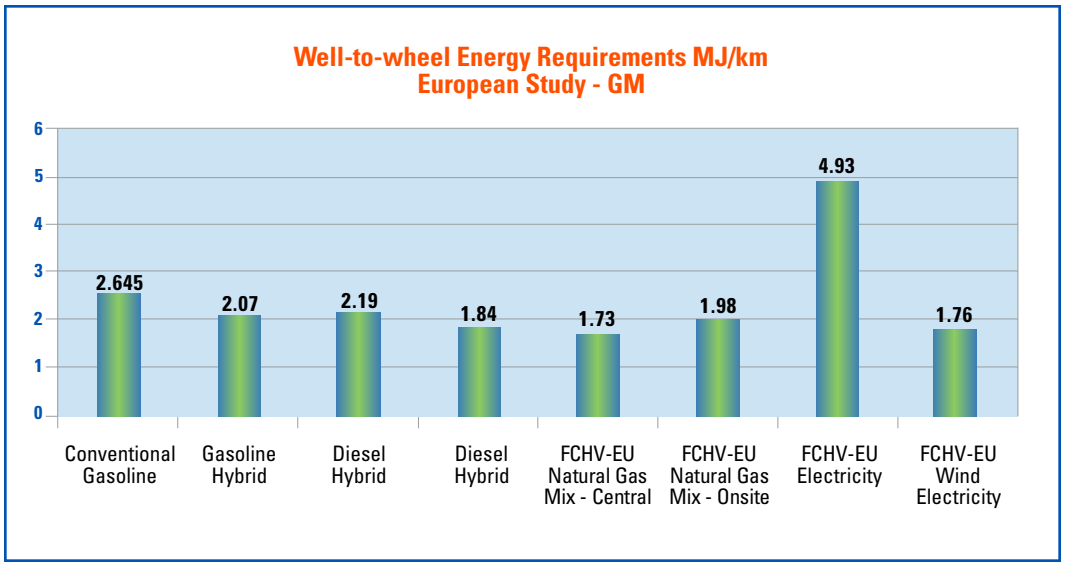
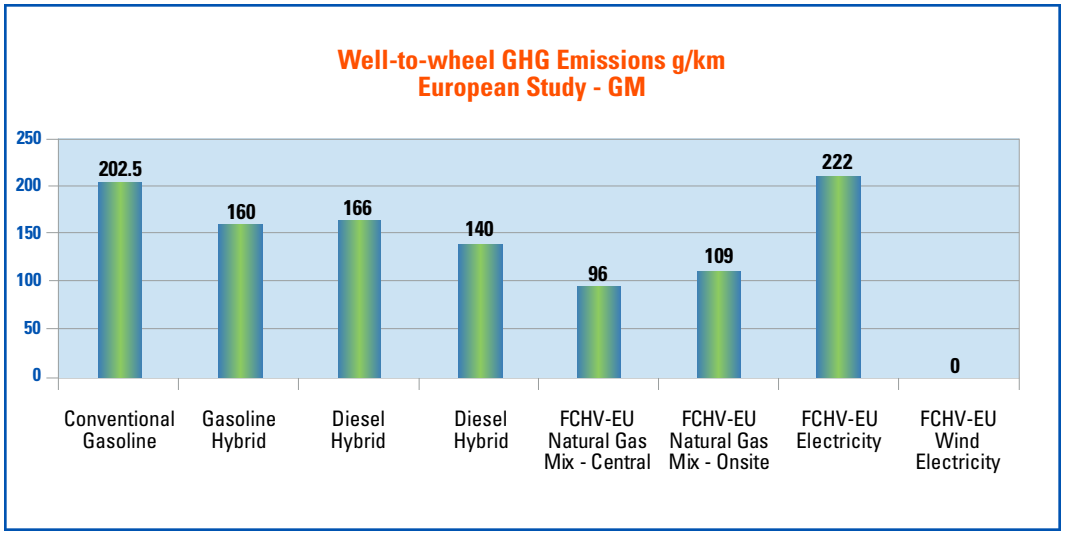


Figure 2



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A Well-to-Wheel Analysis [continued]

Figure 3

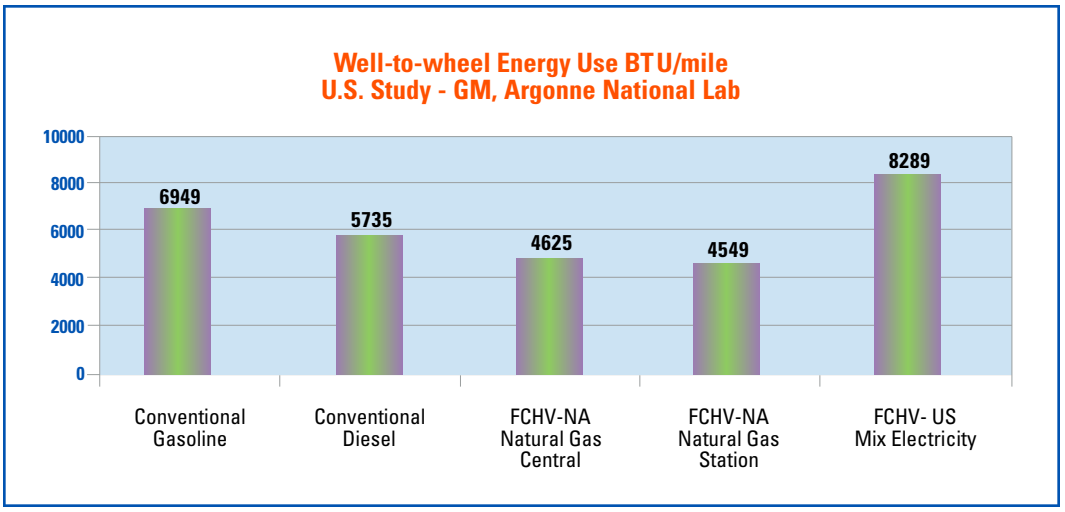
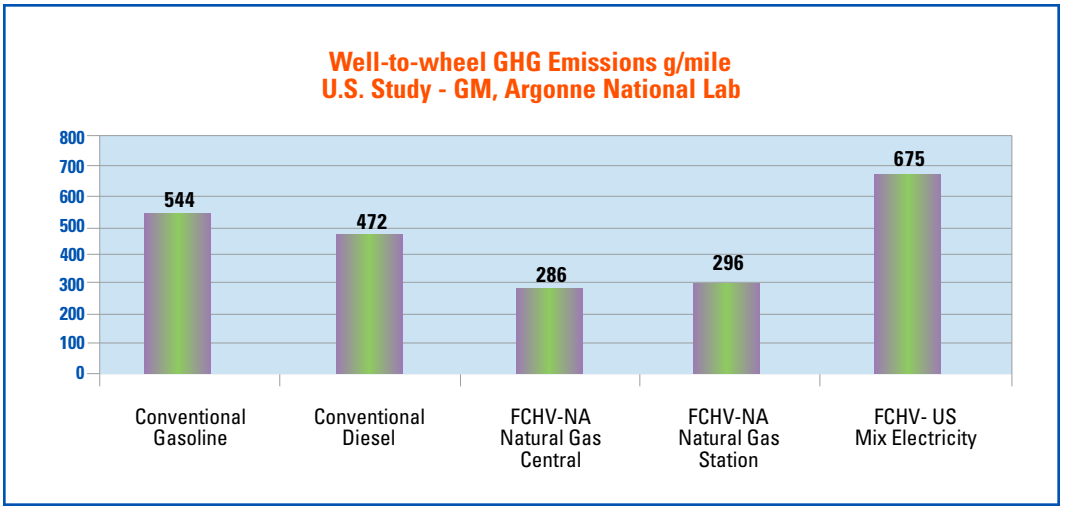


Figure 4



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